Kicker, Septum, Pulsed Magnet Costing Status

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Overview

Parameters are not as well defined as for conventional magnets
- Need extra parameters to design or cost them
  - rise times, fall times, pulse lengths, rep rates for kickers
  - external dimensions of other magnets or obstacles for septums
- These parameters are not always decided yet
- Sometimes they are set arbitrarily to values that make the magnets hard/expensive
- Sometimes optics is not yet designed (damping ring injection, extraction lines)
- Number, location, and function of abort and rate-limiting kickers not certain

Not enough decisions have been made for any costing to be better than a factor of a few
- so I haven't been focusing on that

My focus has been on writing a document to both aid those decisions and the costing
- Audience is area and global groups and people I'll ask later about cost details

For all plausible locations and functions
- Reasoning behind functional requirements
- Calculate or estimate requirement ranges
- State or choose design concept
- Calculate or estimate design parameters

In some cases (damping ring injection and extraction) I'm trying to get designers to change optics and/or layout to make things more reasonable.

The Plausible Location List (1)

Between Electron Source and 5.5 GeV Injector Linacs [wasn't requested]
- BCD has redundant e- sources
- No need for MPS kicker, it should be sufficient to turn off the e-gun
- Turn off DC magnet to send beam to tune-up dump at 71 MeV

Keep-Alive Positron Source [wasn't requested]
- Low-intensity e+ for commissioning e+ ring
- 500 MeV e- accelerator, target, matching device, 400 MeV e+ acceperator
- Not-yet-designed bypass for e- for commissioning e+ ring at reverse polarity
- No need for MPS kicker, turn off DC magnet to send to tune-up dump at 71 MeV

End of Positron Return Line (PRL) [wasn't requested, probably should have been]
- About 300 bunches of 400 MeV positrons would arrive before beam-shutoff
- Useful to allow 1 or N bunches through while dumping rest during tuning
- Need about 0.2 Joule-meters of magnetic energy in aperture to dump the beam
- For 100 ns fill time, and 1 meter kicker, need about 10 MW peak power
- Single-gap thyratron like CX-1154 and single RG-220 cable at 20 kV could do this
- Average power is 3.9 kW for 100 μs pulse, 39 kW for 1 ms pulse (pick one!)
- Average current is 0.2 amps for 100 μs, 2.0 amps for 1 ms (CX-1154 rated for 2.0)
- Making kicker 10 meters long reduces power by factor of 10, current, voltage by $\sqrt{10}$
- Power is in range for FID pulser, don't know about pulse length, avg current
- Kicker could be vacuum striplines with external matching capacitance and load
- Septum could be Lambertson integrated with (undesigned) optics that combines
  - e+ from PRL, keep-alive source e+, keep-alive source e- bypassing target

The Plausible Location List (2)

Note: At 30 MeV/meter, and 0.7 c cable speed, and 340 ns bunch spacing,
about 0.85 bunches per GeV of linac will arrive before beam can be shut off

Between 5.5 GeV Injector Linacs and Damping Rings [not requested, maybe not needed]

- If beam loss is detected at ring, 4-5 more bunches will arrive before gun stops beam
- 1.5 μs pilot bunch delay reduces this to zero extra bunches
- Adiabatic damping reduces emittance which allows smaller apertures, kick angles
- Beam is also stiffer, and this turns out to cancel gain from adiabatic damping
- Same number of Joule-meters of kick is required for positrons
- Same pulser power vs kicker length issues as above
- Need a septum, Lambertson integrated with (undesigned) optics would work

Damping Ring Injection and Extraction

- From e+ acceptance requirements, calculate that 170 kV-meters of kicker is needed
  - i.e., 10 meters at 17 kV, 17 meters at 10 kV, 34 meters at 5 kV
- Bunch spacing may be as small as 3 ns (6 ns in dual positron ring, but may be single)
- Sum of electrical pulse rise time and twice structure delay of less than bunch spacing
  - e.g., 1 ns pulse rise time, 1 ns (30 cm) structure length for 3 ns spacing
  - but 1 ns pulse rise time and 2.5 ns (75 cm) structure length for 6 ns spacing
- With modest limitations on filling pattern, can relax spec on fall time, injector rise time
- There isn't a comfortable existence proof of a pulser
- FID pulsers are closest, but expensive ($50K?) and need lots ($millions!)
- FIDs not proven at 3 MHz, need droop compensation, proven fragile
- Structure probably vacuum striplines, which will get hot from beam (use moly?)
- Probably need (expensive?) filters to keep induced beam signals out of FIDs

The Plausible Location List (3)

Existing damping ring septum parameters, if I understand them, are not feasible
(current density is too high, they probably assumed it's pulsed, it probably can't be)
I'm going to have a meeting with damping ring injection/extraction folks to sort it out

Probably need anti-septum in extraction line to keep power supply tolerances achievable
May want anti-kicker in extraction line to make kicker jitter tolerance looser.

The following haven't all been throught through very far yet

Splitter Upstream of Dual e+ Damping Rings, and Joiner Downstream
- Optics not designed yet, needed (I'm bugging designers)
- The usual length vs strength tradeoff
- Injection splitter power requirement is like other kickers
- Extraction joiner power could be lower because
- Bunch spacing is longer, 100 ns fill times would be OK like PRL or after 5.5 GeV linac
- Could use damping ring injection/extraction pulsers
- Could use longer strips, fewer pulsers, slower rise and fall times with long flat top
- Don't know enough about FID duty factor

Damping Ring Abort
- Want single-turn abort if problem in ring or downstream problem stops extraction
- Kicker needs 20 μs pulse width, very low rate (we hope!)
- Can probably have abort-gap in fill pattern to allow reasonable rise time (50 ns?)
- Thyratron pulser with long striplines and external matching capacitance?
- Dump needs sweeper magnet

The Plausible Location List (4)

Ring to Main Linac Transport Line (5-15 GeV)
- Protection of RTML collimators (but could stop ring extraction to do this)
- Want to let 1-N bunches through for tuning
  - while running full bunch train to keep rings warm, need kicker to dump rest
- BCD has 2 full-power tune-up dumps, one low-power dump upstream of collimators
- Power levels are still a bit up in the air
- 1 to 3 kickers, pulse length from microseconds to milliseconds
- Pulsers like damping ring abort kickers
- Soft request to be able to pick single bunches out of train, would be expensive

Undulator Protection Abort Kicker
- Undulator aperture is much smaller than linac, chicane energy acceptance is small
- Kicker upstream of undulator with 100 ns risetime, kicking 150 GeV beam
- Use chicane magnets as Lambertsons
- Thyratron pulser, long loaded strips
- Dump needs sweeper

Post-Undulator Electron Dump [not really explicit in BCD but needed]
- Want to keep e- going through undulator to make e+ to keep e+ ring warm
- But don't always want full e- bunch train in BDS or even rest of e- linac
- Kicker and full-power dump between undulator and BDS
- Needs full 1 ms pulse length
- Could be either right after undulator (kicker, dump is cheaper) or in early BDS
- Dump needs sweeper

The Plausible Location List (5)

Beam Delivery Protection Abort Kicker
- Protects background collimators that are necessarily close to beam
- Long loaded striplines and many thyratrons
- Not clear if pulse needs to be 100 μs or 1 ms for e+ side
- The e- side needs to be 1 ms long if it's the post-undulator dump
- Long current-sheet septum
- Power level of dumps somewhat up in the air
- These folks talked to me early, so naturally I'm fairly satisfied with the design ;-)

Main dumps need sweeper magnets

Main Linac Abort Kickers
- Concept is to kick beam into blocks inside the vacuum system
- Requires warm insertions for long thyratron kickers, which cryo linac folks hate
- Not really in BCD, not clear if this will be done

The Next Steps

Finish thinking requirements issues through, add to document

Make guess about design choices and parameters, add to document

Guestimate costs at all plausible locations for worst-case requirements
with notes about savings if requirements are relaxed

All kickers and septums have high EDIA cost fraction, any advice?

Probably only the damping ring kickers will look very expensive,
although the protection kickers have an non-trivial extra-tunnel cost
(at least 3 times the kicker cost) that the overall project needs to keep in mind

Damping ring kickers are very uncertain
Being conservative on risetime forces lots of short segments, lots of pulsers
Don't know much about cost of FIDs in large quantity (and single source!)
Don't know if FIDs even work robustly, or if anything else does either!

I think we are supposed to estimate R&D needs separately from BCD costing
damping ring kickers need lots of R&D!